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ORIGINAL ARTICLES.

Fossils from Western Persia.

By Ethel D. Currie, B.Sc., Hunterian Museum, Glasgow University.

(PLATE XI.)

A COLLECTION of fossils from the area of Pusht-i-Kuh, on the western border of Persia, has been forwarded recently to Glasgow University by Dr. W. R. Smellie.

The geology of Luristan in Persia has been studied by J. de Morgan (Miss. Sci. Perse, vol. iii, pt. i, *Etude Géol.*, 1905), whose collection of fossils has been described by Cotteau, Gauthier, and Douvillé (ibid., pts. ii, iii, and iv). With one or two exceptions the fauna collected by Dr. Smellie is similar to that of de Morgan.

Dr. Smellie made his collection from Upper Cretaceous beds and their age is apparently Senonian. The collection consists chiefly of echinoids, but includes also various molluscs, brachiopods, and bryozoa.

The following echinoids are present :—

1. *Cidaris persica* Cotteau & Gauthier, 1895 (ibid., pt. ii, p. 79, pl. xiii, figs. 1–5).

Localities.—Aftâb, Dere-i-Sahir, Endjir-kuh (coll. de Morgan). Shakarau, Warriz, Kabir Kuh 2 (coll. Dr. Smellie).

One specimen is greatly distorted and another is merely a segment of a test. The segment resembles *C. persica* in all respects except that the number of granules in the ambulacral areas increases to eight near the ambitus instead of six as in other specimens.

	DIAM.	HEIGHT.
Dimensions.	14 mm.	9·5 mm.

2. *Rhabdocidaris morgani* Gauthier, 1902 (ibid., pt. iii, p. 145, pl. xx, figs. 3–6).

The exact locality at which de Morgan originally obtained the species has been lost. Dr. Smellie's specimens are a fragment of a test and an interambulacral plate. These are from Warriz.

3. *Salenia cossiva* Cotteau & Gauthier, 1895 (ibid., pt. ii, p. 83, pl. xiii, figs. 13–19).

Localities.—Dere-i-Sahir, Endjir-kuh, Aftâb (de Morgan). Warriz, Atash Gah (Dr. Smellie).

	DIAM. mm.	HEIGHT. mm.
Dimensions.	17	11
	17·5	11
	18·5	12·5
	20	14·5
	23·5	16·5

4. *Goniopygus superbis* Cotteau & Gauthier, 1895 (ibid., p. 101, pl. xvi, figs. 5–10).

Localities.—Dere-i-Sahir, Awasa, Aftâb (de Morgan). Warriz, Anjir (Dr. Smellie).

	DIAM.	HEIGHT.
Dimensions.	24 mm.	14 mm.

5. *Orthopsis morgani* Cotteau & Gauthier, 1895 (ibid., p. 87, pl. xiv, figs. 6–9).

Localities.—Dere-i-Sahir (de Morgan). Shakarau, Warriz, Kabir Kuh 2, Anjir, Kurac Kalul (Dr. Smellie).

	DIAM. mm.	HEIGHT. mm.
Dimensions.	16	10
	26	12
	28	12·5

6. *Orthopsis globosa* Cotteau & Gauthier, 1895 (ibid., p. 89, pl. xiv, fig. 10–14).

Localities.—Aftâb, Dere-i-Sahir (de Morgan). Warriz, Dahnah, Pire Mahommed, Anjir (Dr. Smellie).

	DIAM. mm.	HEIGHT. mm.
Dimensions.	29	17
	29·5	17

The specimens are all more or less distorted. *O. globosa* is distinguished from *O. morgani* by its globular form, its elongated and oblique pores, and the different arrangement of the tubercles.

7. *Actinophyma spectabile* Cotteau & Gauthier, 1895 (ibid., pt. iii, p. 151, pl. xx, figs. 7–10).

Localities.—Endjir-kuh, Aftâb, Tagh-i-Mowla, Meima, Tang-i-Hiana (de Morgan). Warriz, Kâbir Kuh 2, Tang-i-Nyaz (Dr. Smellie).

The specimens are rather broken and distorted but show the sutural impressions and fossettes which distinguish this genus from Cyphosoma.

8. *Coptodiscus noemiae* Cotteau & Gauthier, 1895 (ibid., pt. ii, p. 77, pl. xii, figs. 8–14).

Localities.—Endjir-kuh, Aftâb, Kuh-Mapeul, Dere-i-Sahir, Awâsa (de Morgan). Warriz, Atash Gah, Dahnah, Anjir (Dr. Smellie).

	DIAM.	HEIGHT.
	mm.	mm.
Dimensions.	13	6·5
	13·5	6·5
	17	7
	25·5	7·5
	27·5	10

9. *Holectypus circularis* Cotteau & Gauthier, 1895 (ibid., p. 75, pl. xii, figs. 5–7).

Localities.—Dere-i-Sahir (de Morgan). Dahnah, Anjir (Dr. Smellie).

	DIAM.	HEIGHT.
Dimensions.	27 mm.	13 mm.

10. *Holectypus inflatus* Cotteau & Gauthier, 1895 (ibid., p. 73, pl. xii, figs. 1–4).

Localities.—Aftâb (de Morgan). Shakarau, Warriz, Dahnah (Dr. Smellie).

	DIAM.	HEIGHT.
	mm.	mm.
Dimensions.	47·5	29·5
	26	13
	15·5	9·5

H. inflatus resembles *H. circularis* in many respects, but differs therefrom by being much more timid.

11. *Echinoconus douvillei* Cotteau & Gauthier, 1895 (ibid., p. 70, pl. xi, figs. 9–13).

Localities.—Dere-i-Sahir, Aftâb (de Morgan). Warriz, Kabir Kuh 1 and 2, Dahnah, Anjir, Pire Mahommed, Atash Gah, Tang-i-Nyaz, Kurac Kalul (Dr. Smellie).

	LENGTH.	BREADTH.	HEIGHT.
	mm.	mm.	mm.
Dimensions.	16	14	12·5
	26·5	24	18
	33·5	30	25·5
	43·5	38·5	35·5

The collection also includes two very large individuals not found in situ but on tombs, near the outcrop of Cretaceous beds at Tang Qayah. In one of these the upper half is missing, but the base is perfectly preserved and measures 97 mm. in length. The other specimen, which is not well preserved, has the dimensions :—

LENGTH.	BREADTH.	HEIGHT.
76·5 mm.	72 mm.	61 mm.

12. *Pyrina orientalis* Cotteau & Gauthier, 1895 (ibid., p. 68, pl. xi, figs. 1–8).

Localities.—Dere-i-Sahir, Endjir-kuh (de Morgan). Shakarau, Warriz, Kabir Kuh 1, 2, and 3, Qayah, Anjir, Pire Mahommed, Kurac Kalul (Dr. Smellie).

	LENGTH.	BREADTH.	HEIGHT.
	mm.	mm.	mm.
Dimensions.	18	16	13
	26	22	17·5
	28·5	23·5	18·5
	32	28	22

13. *Pygurostoma morgani* Cotteau & Gauthier, 1895 (ibid., p. 52, pl. viii, figs. 1–5).

Localities.—Aftâb (de Morgan). Worazan, Dahnah, Kurac Kalul (Dr. Smellie).

Specimens poorly preserved and flattened.

	LENGTH.	BREADTH.	HEIGHT.
	mm.	mm.	mm.
Dimensions.	57·5	46	21·5
	62	51	23·5

14. *Parapygus petalodes* Cotteau & Gauthier, 1895 (ibid., p. 58, pl. ix, figs. 4–5).

Localities.—Aftâb (de Morgan). Dahnah, Anjir (Dr. Smellie).

	LENGTH.	BREADTH.	HEIGHT.
Dimensions.	42 mm.	33·5 mm.	21·5 mm.

15. *Catopygus morgani* Cotteau & Gauthier, 1895 (ibid., p. 60, pl. ix, figs. 6–9).

Localities.—Dere-i-Sahir (de Morgan). Kabir Kuh 1 (Dr. Smellie).

	LENGTH.	BREADTH.	HEIGHT.
Dimensions.	32·5 mm.	28 mm.	23·5 mm.

16. *Pseudocatopygus declivis* Cotteau & Gauthier, 1895 (ibid., p. 63, pl. ix, figs. 13–17).

Localities.—Aftâb (de Morgan). Kurac Kalul (Dr. Smellie). One specimen (flattened).

17. *Vologesia tataosi* Cotteau & Gauthier, 1895 (ibid., p. 66, pl. x, figs. 5–8).

Localities.—Aftâb (de Morgan). Dr. Smellie's one specimen is from Kabir Kuh 1. The posterior of the test is broken, but its length must have been about 55 or 56 mm., breadth 46·5 mm., height 34 mm.

18. *Holaster morgani* Cotteau & Gauthier, 1895 (ibid., p. 19, pl. iii, figs. 1–4).

Localities.—Dere-i-Sahir (de Morgan). Warriz, Tang-i-Nyaz (Dr. Smellie).

Specimens poorly preserved and distorted.

19. *Hemipneustes persicus* Cotteau & Gauthier, 1895 (ibid., p. 15, pl. ii, figs. 1–6).

Localities.—Aftâb, Dere-i-Sahir (de Morgan). Worazan, Warriz, Anjir (Dr. Smellie).

20. *Epiaster Smellii* n. sp.

Diagnosis.—Shape of test varies greatly. It may be tumid to flat, and the length may be equal to, or greater than, the breadth. Figs. 1-4 represent four typical specimens.

Peristome is very near the anterior border. It is almost round, and has a small crenulated lip.

Periproct.—The posterior border is truncated obliquely downwards and inwards forming a distinct area outlined by a ring of nodules. The periproct is circular and is situated in the upper portion of this area.

Apical disc.—Almost central; slightly posterior.

Ambulacral areas.—There is no anterior groove; the unpaired ambulacral area is marked by a line of tubercles along each edge. The intermediate space is covered by fine granules with a few smaller tubercles interspersed. The pores, only visible in worn specimens, are small and round and disposed in oblique pairs at comparatively great distances apart.

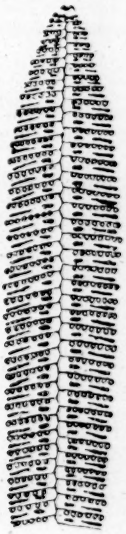


FIG. 5.—Part of one of the paired ambulacral areas of *E. Smellii*. × 6.

The paired ambulacral areas (Fig. 5) are sub-petaloid and level with the test, the anterior pair being more divergent than the posterior pair. The plates are small and their length is three to four times their height. Each contains a pair of conjugate pores, set obliquely and both elongated, the exterior more so than the interior one. The pore-pairs are separated by a ridge bearing six to eight small granules along the upper edge of each plate. The number of pore-pairs in the anterior ambulacral pair is usually greater than that

in the posterior pair by one, two, three, or four pairs, according to the height of the individual, the higher individual having the greater difference. In a few specimens, however, the number of pore-pairs in the anterior and posterior ambulacral areas is the same. The space between the pore zones is very narrow and in a groove; its width is a little less than the length of the larger pore.

Interambulacral areas.—One plate corresponds to seven in the ambulacral area. Eight plates in a column can be counted above the ambitus. The tubercles, which are distributed unevenly over the areas, are largest and show rough alignment on the adambulacral parts. The intertubercular spaces are covered with small granules which form scrobicules round the tubercles (Fig. 6.) The number of tubercles increases towards the ambitus, and on the inferior surface they are very numerous and close together, except in the areas corresponding to the posterior ambulacra which are devoid of tubercles.

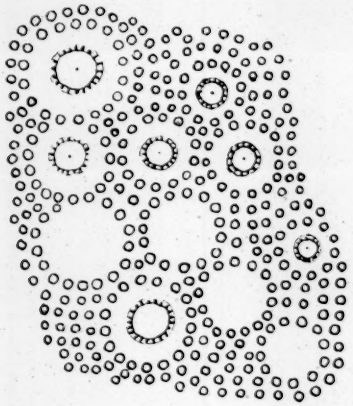


FIG. 6.—Arrangement of tubercles, magnified about twelve times, and showing areas where tubercles have been knocked off.

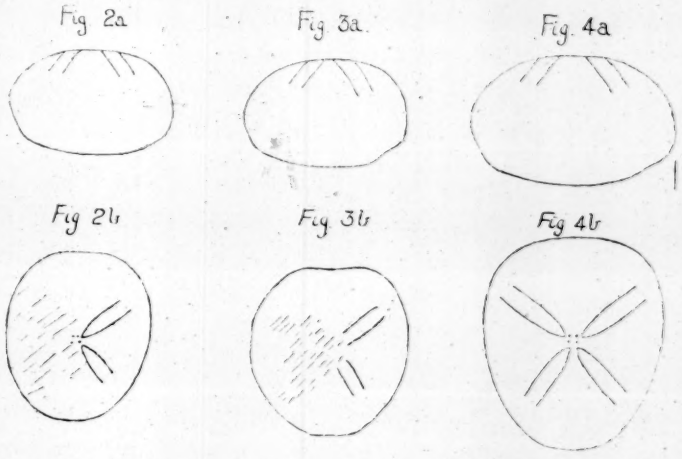
Dimensions.—The following are the dimensions of the specimens given as types in Figs. 1–4 :—

LENGTH.	BREADTH.	HEIGHT.
mm.	mm.	mm.
39	37	29
29	26	18
29·5	28·5	19·5
36	32	22·5

The dimensions and the shape of these specimens seem very divergent for one species, but as they are exactly similar in other respects it is best to regard them as different varieties of the species.

This view is favoured by the fact that some specimens do not appear to belong to any of these types, but to an intermediate one.

An interesting point in connexion with *E. Smellii* is that several have, in the right anterior part of the test, a curious asymmetric bulge. In some it is very marked, in others it is hardly noticeable, and in others, again, it is absent. Since it is not diagnostic of the species, it is probably due to conditions of pressure under which the animal has been preserved. If so, it is remarkable that the right anterior portion of the test should be affected in every case. It is apparent to a slight extent in Figs. 2*b* and 3*b*.



FIGS. 2, 3, 4*a*.—Outlines of profiles of three other types of *E. Smellii*. Less than nat. size.

FIGS. 2, 3, 4*b*.—Outlines of same specimens from above. Less than nat. size.

Distribution.—Collected by Dr. Smellie from Senonian beds in the following localities: Shakarau, Warriz, Atash Gah, Anjir, Anerun, Pire Mahommed, Tang-i-Tima, Qayah, Kabir Kuh 1, 2, and 3.

Affinities.—*E. Smellii* differs from all others except *E. aquitanicus* d'Orbigny, 1853 (*Pal. franc. Terr. Cret.*, 6, p. 199, pl. 863), by the absence of an anterior sulcus. It shows a close resemblance to *E. aquitanicus*, but differs therefrom by having (1) the pores in the paired ambulacral areas set obliquely, (2) the granules in the ambulacral areas not extending to the median suture, (3) the pore-pairs in the unpaired ambulacra round, and further apart than in *E. aquitanicus*, (4) the largest tubercles on the adambulacral parts of the interambulacral areas and on the inferior surface.

21. *Iraniaster morgani* Cotteau & Gauthier, 1895 (op. cit., p. 28, pl. iv, figs. 1–12).

Localities.—Awasa (de Morgan). Shakarau, Warriz, Kabir-kuh 1, 2, and 3, Anjir, Pire Mahommed (Dr. Smellie).

Dimensions.

LENGTH.	BREADTH.	HEIGHT.	HEIGHT IN CENTIEME OF LENGTH.
mm.	mm.	mm.	mm.
51·5	49	25·5	50
44	41	23·5	53
49	45	27	55
57·5	52·5	33	57
55	52	32	58
45	42	26	58

The height varies greatly. The more tumid specimens resemble in shape *I. Douvillei* (ibid., p. 30, pl. v, figs. 1–6), from which they are distinguished by having a more marked anterior groove and the fasciole nearer the ambitus.

22. *Hemiaster longus* Cotteau & Gauthier, 1895 (ibid., p. 40, pl. vii, figs. 1–5).

Localities.—Awâsa (de Morgan). In Dr. Smellie's collection the best preserved and most numerous specimens are from Shakarau; others from Warriz and Atash Gah are poorly preserved.

	LENGTH.	BREADTH.	HEIGHT.
	mm.	mm.	mm.
Dimensions.	17	14·5	10
	26·5	21	15
	31	24·5	17
	33	27	20
	42·5	33·5	26
	42·5	36	26·5

23. *Hemiaster noemiae* Cotteau & Gauthier, 1895 (ibid., p. 35, pl. vi, figs. 1–7).

Localities.—Awasa (de Morgan). Shakarau, Warriz, Atash Gah, Anjir, Kabir Kuh 1 and 2, Dahnah, Pire Mahommed, Tang-i-Nyaz (Dr. Smellie).

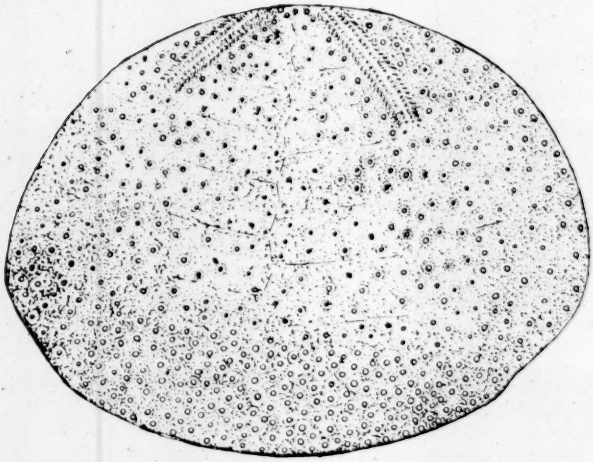
	LENGTH.	BREADTH.	HEIGHT.
	mm.	mm.	mm.
Dimensions.	13	12	9
	22·5	20·5	14·5
	26	24·5	19
	32	30	22·5
	34	31·5	25
	38·5	36	26·5

24. *Hemiaster morgani* Gauthier, 1902 (ibid., pt. iii, p. 131, pl. xix, figs. 3–4).

Localities.—Arkwase (de Morgan). Pire Mahommed (Dr. Smellie).

Dr. Smellie's specimen is distorted but is otherwise perfectly preserved. Its length is about 60 mm.

FIG. 1*a*.



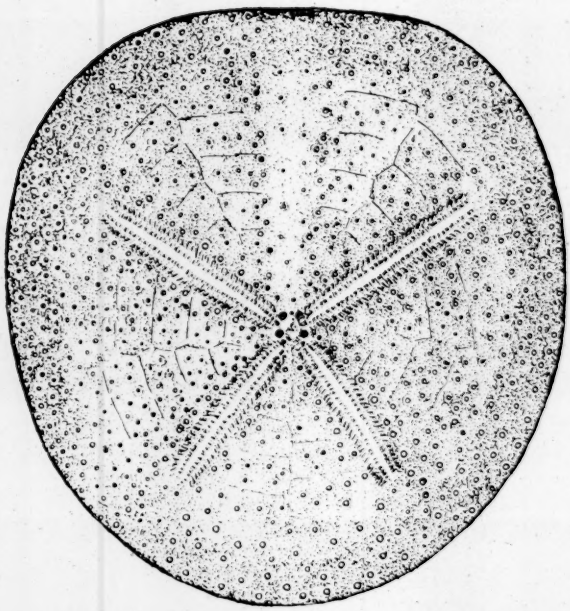


FIG. 1*b*.

EPIASTER SMELLII, n.sp.

To face p. 55.

The collection includes the following molluscs :—

	Localities.
Lopha dichotoma Bayle.	Kabir Kuh 1, Warriz, Pire Mahommed, Shakarau.
Lopha zeilleri Bayle.	Pire Mahommed, Shakarau (along with *Ostrea* cf. *janus* Coquand).
Lopha pectinata (Lam.).	Kurac Kalul, Kabir Kuh 1, Warriz, Pire Mahommed.
Lopha morgani Douvillé (ibid., pt. iv, p. 275, pl. xxxvi, figs. 1–7).	Dere-i-Sahir (de Morgan). Anerun, Pire Mahommed.
Lopha ungulata (Schlotheim).	Kurac Kalul.
Exogyra matheroni (d'Orbigny).	Warriz, Pire Mahommed, Atash Gah, Anjir, Kurac Kalul, Dere-i-Sahir.
Pseudoheligmus morgani Douvillé (ibid., p. 264, pl. xxxv, figs. 3–5).	Dere-i-Sahir (de Morgan). Warriz, Tang-i-Nyaz, Dahnah.
Spondylus subserratus Douvillé (ibid., p. 268, pl. xxxv, figs. 8–14).	Awasa (de Morgan). Anjir (Dr. Smellie).
Plicatula hirsuta Coquand.	Warriz.
Neithea tricostata Bayle.	Atash Gah.
Trigonia orientalis Forbes.	Anjir.
Gryphæa vesicularis (Lam.).	Shakarau.

The collection also includes two species of brachiopods.

Terebratula brossardi Thom. et Pér.	Atash Gah.
Terebratula toucasi (d'Orbigny).	Warriz, Anjir, Pire Mahommed.

CONTRACTIONS.

Contraction used.	*Exact Locality.*
Kabir Kuh 1.	Kabir Kuh, west of Sar-ab-i-Maima.
Kabir Kuh 2.	Kabir Kuh, north of K.B. Point.
Kabir Kuh 3.	Base of Kabir Kuh, between Chashma-i-Kani Pahan and Arkwase.
Anjir.	Junction of Rivers Gulgul and Dalau, 4–5 miles north-west of Anjir Trigonometric Station.
Pire Mahommed.	Five miles west of Pire Mahommed on the road to Amirabad.
Warriz.	Four to five miles south and south-east of Deh Bala.
Anerun.	Valley north of Anerun.

EXPLANATION OF PLATE XI.

FIG. 1*a*.—Profile of a specimen of *E. Smellii*. Twice nat. size.
FIG. 1*b*.—View of same specimen from above. Twice nat. size.

I must acknowledge my indebtedness to the Carnegie Trust, who have furnished means for publication of the plate.

Some Remarkably Preserved Brachiopods from the Lower Magnesian Limestone of Durham.

By C. T. Trechmann, D.Sc., F.G.S.

(PLATE XII.)

SEVERAL quarries in the neighbourhood of Shildon, near Bishop Auckland in South Durham, display interesting sections of the Lower Magnesian Limestones and the beds on which they rest. At present the most instructive is that at East Thickley, near Shildon railway station, and as there seems a probability in the near future of this quarry becoming obscured by pit refuse, a record of the section exposed in it seems to be desirable. A large part of the rock-face has already been so obscured. A short distance south-east of this one other quarries exist closely adjoining the railway, but they are now almost entirely filled up with rubbish though sections in the railway cutting may still be seen. About a mile south-west of Thickley across the railway a quarry is at present being worked near Midderidge Grange, and seems to be the one in which important reptilian and other vertebrate remains were found in the Marl Slate many years ago. Notable among these is the headless skeleton of *Proterosaurus Huxleyi* Hancock & Howse,[1] each bone of which has the interior filled with galena. This and other important specimens are now in the Hancock Museum at Newcastle-on-Tyne. At present, however, the only rock visible in Midderidge Quarry is the dolomitic Lower Magnesian Limestone, in which no fossils are to be seen. These quarries are either, as in the case of East Thickley, situated on the junction of the Permian with the Coal Measures, or, in the case of Midderidge, very close to the junction.

Returning to East Thickley (Fig. 1), where about 45 feet of rock is exposed in the quarry face, we find that the lowest bed consists of sandstones of the Coal Measures between the Harvey & Brockwell seams. These are generally massive and current-bedded; about 12 feet of them are exposed and until a few years ago they were quarried as building stone. Above these come the Marl Slates, about 8 feet thick. At the base of the Marl Slate and resting on the Coal Measures there is an irregular bed a few inches thick of yellow dolomitic marl with sand and small rounded pebbles chiefly of quartz. It appears to fill up shallow depressions on the denuded surface of the Coal Measures and may, perhaps, be regarded as the equivalent of the Yellow Sands of the Permian, which are absent in this section. This pebbly bed is interesting as it contains numerous specimens of *Lingula credneri* Gein., the phosphatic shells of which are perfectly preserved even to the extent of retaining the different shades of colour on the bands of growth. Some of these *Lingula* valves are brown in colour, while others are bluish grey.

The overlying Marl Slate still yields fish and plant remains, or did

[1] *Q.J.G.S.*, vol. xxvi, 1870, p. 568.

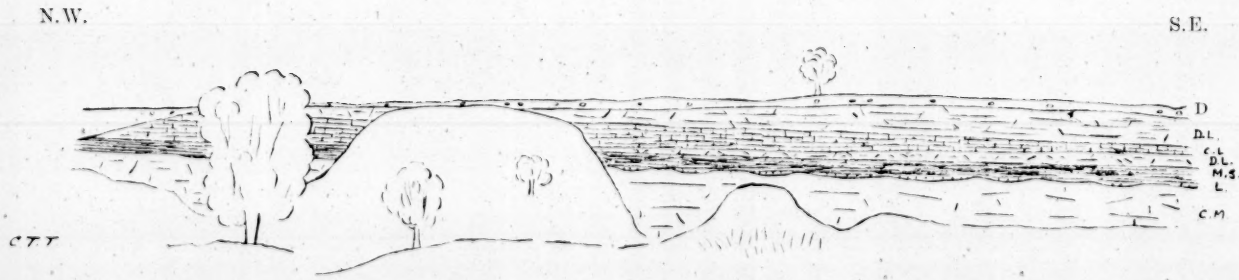


FIG. 1.—Diagrammatic sketch of the section in East Thickley Quarry, near Shildon, South Durham. Thickness of rock exposed about 45 feet. C.M., Coal Measures; L., Pebbly dolomite marl with *Lingulae*; M.S., Marl Slate; D.L., Dolomitic Lower Limestone; C.L., Fossiliferous calcareous Lower Limestone thinning out to the south-east; D., Glacial drift. Part of quarry obscured by refuse heaps and vegetation.

so plentifully until a few years ago while the underlying sandstone was being quarried.

Dr. Coggin Brown found here a specimen of the teeth and shagreen of *Janassa bituminosa* Schloth. some years ago when he and I were collecting in the Marl Slate at this place.

The Marl Slate passes up rather gradually into the compact dolomitic Lower Magnesian Limestone, and this in turn merges up into a bed of calcareous limestone, which is fairly thick in the north-west end of the quarry, but gradually thins out towards the south-east. This is again overlain near the top of the section by dolomitic rock very similar to that above the Marl Slate. The dolomitic rock appears to have been deposited as dolomite, and is only very sparsely fossiliferous, but the calcareous beds have yielded a very interesting suite of excellently preserved fossils, to some of which I wish to draw attention.

The calcareous Lower Magnesian Limestones, which consist of very pure limestone in South Durham, are of rather unusual interest, as they seem to occur as lenticular masses in the dolomite. In many Permian sections the whole of the Lower Limestone is dolomitic throughout, but in others the calcareous beds attain a considerable thickness.

At Raisby Hill Quarries, near Coxhoe, 9 miles north-east of Thickley, they are about 60 feet thick, but are much less fossiliferous than at Thickley. In a boring recently put down near Sheraton, in South Durham, 6 miles east of Coxhoe, the calcareous beds proved to be about 120 feet thick, but no fossils appeared in the cores.

I have nowhere seen the calcareous Lower Magnesian Limestone so fossiliferous as it is at East Thickley, and the rock appears on examination of weathered surfaces with a lens to be made up of organic fragments, though, strangely enough, a thin slice reveals practically no structure. I have already published analyses of these rocks.[1]

Some remarkable blocks of limestone have recently been collected, the weathered surfaces of which, after being cleaned and developed, show something of the manner in which the Brachiopods lived, associated together on the bed of the Permian sea. Two of these seem to deserve special attention and illustration.

The first, represented by a sketch (Fig. 2), exhibits a specimen of *Productus horridus* Sow., bearing on one side two thick slightly curved spines which spring from the ear of the ventral valve and measure between 2½ and 3 inches in length. Near the end of one spine (A) a specimen of *Epithyris elongata* Schloth., now rather crushed, has fixed itself by the foramen of its ventral valve, the back of which is visible on the slab. The oval outline, gently rounded surface, absence of median sinus and punctation of the shell in this

[1] "Lithology and Composition of Durham Magnesian Limestones": *Q.J.G.S.*, vol. lxx, 1914, p. 247.

specimen are noticeable. At the extremity of the other spine (*b*) a small *Strophalosia* has fixed itself by attaching its ventral beak and by winding the long, matted spines of its ventral valve around the *Productus* spine. The specimen shows the spines of the ventral valve, the area of both valves and the surface of the dorsal valve. The latter is nearly flat and is devoid of spines but the concentric lamellar growth-lines are well seen, together with the hinge teeth of the ventral and a median septum in the dorsal valve.

It does not closely resemble any of the specimens of *Strophalosia* illustrated by W. King in his Permian Monograph, pl. xii; these, however, are, with the exception of one from Whitley, from various localities in the Shell Limestone of the Middle Magnesian Limestone of Durham.

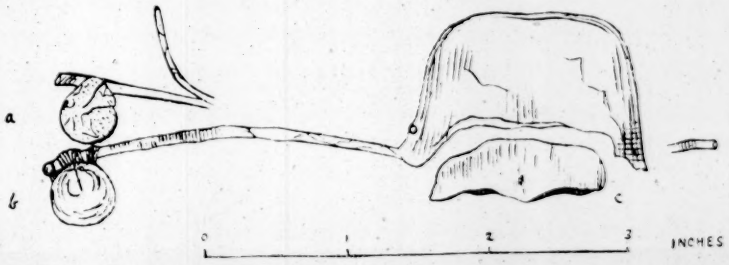


FIG. 2.—Sketch of a specimen of *Productus horridus* Sow., with long spines on the ventral valve. c, part of interior of the dorsal valve; a, a specimen of *Epithyris elongata* Schloth.; b, a specimen of *Strophalosia lamellosa* Gein.

Calcareous Lower Magnesian Limestone, East Thickley: Quarry, Durham.

Neither does it agree with any of T. Davidson's figures of English Permian specimens, illustrated in his monograph of Permian Brachiopoda, pl. iii. Turning to Geinitz,[1] however, one finds a species which he calls *S. lamellosa*, in which the dorsal valve is almost circular in outline, nearly flat, and free from spines. I have some specimens collected and labelled by the collector, Robert Eisel, of Gera, as belonging to this species, which very closely resemble the specimen under discussion. They are said to come from zone 3[2] of the Lower Zechstein, of Roschitz, Röpsen, near Gera, and are in a remarkably finely preserved testiferous state, as are the Thickley specimens also. The species *S. lamellosa* is questionably quoted by King as a synonym of his *S. Morrisiana*. Davidson figures several specimens all from the English Shell Limestone, and calls them *S. lamellosa* Gein., var. *Morrisiana* King, and var. *Humbletonensis* King. He discusses the matter further in a supplement to his

[1] *Der Dyas*, Leipzig, 1861, pl. xviii, figs. 1–7.

[2] These zones appear to be local divisions established in the Gera district. So far as I remember from conversation I had with R. Eisel in 1913 the zones of the lower Zechstein are characterized by different shape-variants of *Productus horridus*.

Permian Brachiopoda (p. 269), and expresses the opinion that all the known British Permian Strophalosias are referable to two species. He is, however, uncertain whether one is quite justified in placing King's *S. Morrisiana* among the synonyms of *S. lamellosa*. Geinitz (p. 98) is emphatic that *S. lamellosa* is a distinct species and I think most palæontologists nowadays would agree that this is so.

The second block of limestone[1] is illustrated nearly natural size by a photograph (Pl. XII). The most conspicuous fossil on it is *Productus horridus*, of which there are three examples, the largest, a ventral valve, measuring about 3 inches across, with spines nearly or quite 3 inches long. Another smaller specimen, of which the apical region of both valves is exposed, shows the long curved spines springing from the hinge line and surface of the dorsal or concave valve as well as from the hinge line of the ventral valve. Among the other fossils are some exceptionally large specimens of *Streptorhynchus pelargonatus*, Schloth. Near the top corner of the slab (B), the crushed specimens of two ventral valves of this brachiopod are seen together with the interior aspect of a dorsal valve. The sharp radial ribs are noticeable. They agree in size and all other respects with specimens I have from zone 3 of the Lower Zechstein of Roschitz, Röpsen, near Gera, and are very much larger than the dwarfed specimens that commonly occur in the lower parts of the Shell Limestone reef in Durham. A ventral valve of *Spirifer alata* Schloth. (C) is also visible.

Several Strophalosias occur on the slab, the most remarkable of which is that at (A). It is attached to the end of the long spines of two different *Producti*, the shell of one of which is broken away from the slab. The spines of its ventral valve are very numerous, massed together, directed backwards and twined round and about the *Productus* spines. The areas of both valves are visible; that of the ventral is rather high and concave. The dorsal valve is deeply concave and covered with massed spines much shorter than those of the ventral valve, and mostly directed inwards to the centre without, of course, being attached to anything. This specimen again resembles very closely indeed some examples of *Strophalosia goldfussi* Münster I have from Trebnitz, near Gera, belonging to zone 4 of the Lower Zechstein. I obtained these specimens also from Robert Eisel. Similar, but rather less well preserved, examples are illustrated by Geinitz in his *Dyas*, pl. xvii, fig. 21-24.

Geinitz remarks that this species as it appears in Germany does not seem to have been found in England, and he refers all the specimens hitherto described as *S. goldfussi* by English authors to *S. excavata* Gein. Another *Strophalosia* appears on the slab with its ventral apex apparently attached to the left ear of the large *Productus*, and shows only a poorly preserved concave dorsal valve which seems

[1] This specimen was found by Dr. Stanley Smith, F.G.S., during a recent visit by him and myself to Thickley, and he kindly placed it at my disposal.

Surface of a Block of Calcareous Lower Magnesian Limestone from East Thickley Quarry, Durham, about ½ natural size.

To face p. 543.]

to belong to *S. Morrisiana* King, a species which is rather common at Thickley.

I shall not in this short note attempt to give a complete list of the rather numerous fossils that occur at Thickley, as I am preparing a synoptical table of the fauna of the chief fossiliferous horizons of the Durham Permian for a future paper. The difficult group of the Permain Strophalosias of England is one on which much might be written, including among them the curious small form called by King *S. parva*, which domiciles itself in the interior of empty valves of *Productus horridus* in the Shell Limestone reef. A sound revision of the Permian fauna is a task which would undoubtedly repay the effort expended on it.

EXPLANATION OF PLATE XII.

Surface of a block of Calcareous Lower Magnesian Limestone from East Thickley Quarry, Durham, about $\frac{2}{3}$ natural size. In middle *Productus horridus* Sow., with long spines. At A, a *Strophalosia goldfussi* Münst. attached to the *Productus* spines; BBB, specimens of *Streptorhynchus pelargonatus* Schloth.; C, specimen of *Spirifer alata* Schloth.

On the Rocks of the Avon Section, Clifton.

By Sidney H. Reynolds, M.A., Sc.D.

AN account of the lithological succession of the rocks of the Avon Gorge was given at the Bournemouth meeting of the British Association in 1919, and a summary of the rock-characters mainly from the lithological aspect was published in the Geological Magazine (1919, p. 523). Further work has now been done, and a full account of the rocks is published in the current issue of the *Quarterly Journal of the Geological Society*.[1] The following summary prepared for the above paper was considered redundant owing to the fact that the matter it contains is already incorporated in the text of the paper. In view, however, of the importance and accessibility of the Avon Section it is thought that a brief statement such as the following, in which the rock-characters are summarized firstly from a stratigraphical and secondly from a lithological aspect may be useful.

I. Description of the Rocks from the Stratigraphical Aspect.

A. *The Cleistopora Beds.*

The Modiola Shales K_m.—The lower beds, which are ill-exposed, consist of sandy shales, of tencalcareous, and impure limestone. The upper beds consist of thin-bedded, often sandy, and rubbly limestones with reddish shaly partings. Small lamellibranchs, ostracods, and calcareous algæ are the most characteristic organisms. Small gastropods, brachiopods, and crinoids are also

[1] *Quart. Journ. Geol. Soc.*, vol. lxxvii, 1921, p. 213.

frequent and tubicolous annelids occur. The beds are of shallow-water character, and constitute the earliest *Modiola* phase of the Avon Section.

The Bryozoa Bed (horizon *a*) consists of massive ferruginous limestone, mainly composed of crinoids, but with very plentiful bryozoa at certain levels.

K_1.—Consists of shale and mudstone alternating with thin-bedded limestone. The principal limestone builders are crinoids and brachiopods. Ostracods and bryozoa are sometimes plentiful. In the "Palate Bed" at the base Elasmobranch teeth are abundant.

K_2.—Only the upper part of this horizon is well exposed, the rocks consisting of thin-bedded highly fossiliferous limestone alternating with shale. Crinoids and brachiopods are the principal limestone builders. Ostracods and bryozoa are plentiful at some levels. A little dolomitization has taken place in some of the highest beds.

B. *The Zaphrentis Beds.*

Horizon β.—On the right bank this horizon consists of rather massive limestone with crinoids and brachiopods. On the left bank the rock is thinner-bedded.

Z_1.—The lower beds are crinoidal and brachiopodal limestones overlain by thick-bedded dolomite, capped by a chert band. The upper beds are dark dolomitized crinoidal limestone (petit granite), with many fossils, especially brachiopods.

Z_2 *and horizon* γ.—Consists almost throughout of dark crinoidal limestone (petit granite). The matrix is almost everywhere completely dolomitized, but where this has not taken place foraminifera and *Calcisphaera* become for the first time plentiful. The larger fossils, particularly the crinoids, resist dolomitization and are the chief limestone builders. Brachiopods are less and corals more common than in Z_1. The "Fish Beds" at the top of Z_2 contain numerous Elasmobranch teeth and spines.

C. *The Syringothyris Beds.*

C_1. (*a*) *The Laminosa Dolomite.*—Consists of crinoidal limestone almost completely replaced by dolomite. At the top is the sub-oolite bed with abundant *Chonetes* and *Orthotetes*.

C_2 (*b*) *The Caninia Oolite.*—This is a fine-grained white oolite, the grains often enclosing foraminifera. Other fossils are scanty.

C_2. *The Caninia Dolomite.*—The lower beds are composed of grey and pale dolomite alternating with calcareous shale and mudstone occasionally algal. The dolomite was originally in the main oolitic or foraminiferal limestone. The upper beds are mainly china-stones with ostracods and calcareous algæ. The *Caninia* dolomite commences the second *Modiola* phase of the Avon Section.

D. *The Seminula Beds.*

S_1 continues the second *Modiola* phase of the Avon Section.

S_1 (*a*).—Mainly calcite mudstones with algal, ostracodal, and *Seminula* layers and a *Lithostrotion* (*Diphyphyllum*) band at the base. Overlying these beds are limestones with *Lithostrotion martini* and thick shaly partings.

S_1 (*b*).—Mainly dark, massive, much dolomitized limestones, with abundant *Lithostrotion martini*, but including shaly partings and some bands of china-stone type.

S_2 (*a*) *The Seminula pisolite and associated rocks.*—These consist of shallow-water deposits—calcite mudstones, dolomites, and pisolites associated with massive dolomitized *Lithostrotion* limestones. At the top are dolomites with three chert bands.

These rocks form the upper part of the second *Modiola* phase of the Avon Section.

S_2 (*b*) *The Seminula Oolite.*—The lower part consists of massive white fossiliferous oolite, the grains being often formed round foraminifera. The upper beds, in addition to oolites, include foraminiferal limestones.

S_2 (*c*).—The rocks of this level are chiefly massive foraminiferal limestones with *Chonetes* and *Lithostrotion* bands, and are often considerably dolomitized. The upper beds include china-stones and pisolites and commence the third and last *Modiola* phase of the Avon Section.

S_2 (*d*) *The "Concretionary Beds".*—These consist largely of china-stones with bands of *Seminula* pisolite and more rarely oolitic layers, but their most marked feature is afforded by the numerous "Concretionary" (algal) bands.

E. *The Dibunophyllum Beds.*

D_1.—The lower part consists of highly foraminiferal and coral-bearing white limestone associated with layers of coarse red oolite, and numerous bands of pseudobreccia. Thin shaly partings often separate the limestone bands. The upper part consists in the main of bands of coarse red oolite alternating with thick bands of shale and red grit.

D_2.—Except for the fact that this horizon commences with a band of quartz conglomerate, the lithological types are identical with those in D_1. The lower beds are chiefly grey foraminiferal limestones and pseudobreccias, in the middle part coarse red oolites prevail, while the upper beds include much red grit and shale.

II. Description of the Rocks from the Lithological Aspect.

(*a*) *Calcareous Rocks.*

These may be classified according to the nature of their chief organic constituent :—

(1) *Algal Limestones* are abundant in all the rocks which accumulated under *Modiola* phase conditions, viz.: (*a*) in K_m; (*b*) at the top of the *Caninia* dolomite, C_2; (*c*) in the lower part of S_1; (*d*) in the *Seminula* pisolite bands of the lower part of S_2; (*e*) in the Concretionary Beds of the upper part of S_2. Calcareous algæ have also been met with in the lower part of C_2 and the middle part of S_2.

Mitcheldeania is the most persistent form ranging from the extreme base of the section to the top of S_2. *Ortonella* is characteristic of the K beds. *Solenopora* is found occasionally in the K beds. *Spongiostroma* associated with subordinate *Mitcheldeania* is prevalent in the calcite mudstones which are so abundant throughout C_2 and S. *Girvanella* tubules are seen forming the centre round which some of the oolitic grains in the lower part of D_1 have formed. *Aphralysia* was found in C_2 and S_2 (*d*).

The algal material commonly tends to form nodules, but in K_m it also occurs as narrow layers interbedded with gritty bands, and in S_1 the *Spongiostroma* masses tend to form undulating sheets. In S_2, especially in the lowest beds, the *Seminula* pisolite type prevails, characterized by the *Spongiostroma* and sometimes *Mitcheldeania* layers being arranged concentrically, often round *Seminulæ*. Lastly the Concretionary Beds of the top of S_2 form the most important of the algal developments, *Mitcheldeania* being the prevalent form.

(2) *Foraminiferal Limestone.*—Foraminifera first begin to be fairly common in Z_2. They are abundant in the *Caninia* oolite and are seen frequently in non-dolomitized bands (whether belonging to the calcite-mudstone series or to the oolites) in C_2 and the whole of S. They occur in great abundance in the white limestones of the upper part of S_2, and the lower part of D_1. They abound in the pseudobreccias. *Calcisphaera* first becomes plentiful in Z_2.

(3) *Coral Limestone.*—Zaphrentid corals play an appreciable part as limestone builders throughout the *Zaphrentis* zone, and there is a well-marked *Caninia* band in S_1. Bands full of *Lithostrotion martini* are most characteristic of the S beds, and there is a well-known band of basaltiform *Lithostrotion* in S_1. The abundance of corals in the D beds is so familiar that it need not be emphasized.

(4) *Crinoidal Limestone.*—Crinoids occur in considerable abundance throughout practically the whole Lower Avonian, except in the *Modiola* shales and *Caninia* oolite, but are specially plentiful in (*a*) the Bryozoa Bed, (*b*) K_1 and K_2, (*c*) the petit granite of the whole *Zaphrentis* zone. In the Upper Avonian crinoids are not specially characteristic, but occur in some abundance, and often reach a very large size in the white limestones of the D beds. Sections of echinid spines presumably to be attributed to *Palechinus*,

have been met with at various levels throughout practically the whole section from the lower part of K_1 to D_2.

(5) *Brachiopod Limestone.*—Brachiopods associated with crinoids are very characteristic of K_1 and K_2. They are abundant in horizon β and Z_1, often forming well-marked bands in which *Spirifer clathratus* and *Chonetes hardrensis* are the most conspicuous forms. *Seminula*-bands are one of the most characteristic features of the S beds. *Productus* and *Chonetes papilionacea* bands are frequent throughout S and much of D. The suboolite bed (top of C_1) is also a strongly marked band of *Chonetes papilionacea*.

(6) *Bryozoa* occur abundantly in the Bryozoa Bed at the base of K_1 and in the upper part of K_2, and are met with at various levels throughout the whole section.

(7) The presence of worms is often indicated where *Modiola* phase rocks are met with, thus small spirorbid annelids are common in K_m and C_2. Tubular bodies probably due to worm borings are characteristic of the very white calcite-mudstones of S_1 and S_2 (*a*). Some of the shales of S_1 are full of "worm tubes".

(8) *Ostracods* are very plentiful wherever the rocks are shaly or of the calcite-mudstone type, viz. throughout K, at the top of C_2, in the lower part of S_1, and at certain levels in upper S_2.

(9) *Molluscs* do not play an important part, though small lamellibranchs and small gastropods are plentiful in certain bands in K_m, and *Euomphalus* occurs sparingly in S_1. Small gastropods seem characteristic of *Modiola* phase conditions, occurring in the calcite mudstones of S_1 as well as in K_m.

(10) Elasmobranch teeth and spines are very characteristic of the "Palate Bed" just above the Bryozoa Bed in K_1, and of the "Fish beds" at the top of Z_2.

Oolites occur at the following levels:—

(1) In the upper part of C_1, the *Caninia* oolite.

(2) At the middle of S_2, the *Seminula* oolite. Both these are very white rocks and of great thickness.

(3) Thin bands of oolite occur at various levels in the Concretionary Beds of S_2 and in C_2.

(4) Thick bands of coarse red oolite occur at intervals throughout the D beds.

(*b*) *Siliceous rocks.*

Grits are met with only in the D beds (D_2 and upper part of D_1), where bands may reach a thickness of 20 feet. Sandy limestones are frequent in K_m and K_1. Quartz grains occur frequently throughout the limestones of the C, S, and D beds, and at many levels secondary growth has converted them into doubly terminated crystals. In other cases the crystals seem to have been formed independently of pre-existing grains. Bands of chert due to the replacement of the limestone occur (*a*) near the middle of Z_1, (*b*) just below the *Seminula* oolite, and (*c*) between the *Seminula* oolite and the Concretionary Beds. Partial silicification (beekite)

affects the fossils of upper K_2, β, and Z_1, and the Lithostrotiont corals, and occasionally the *Seminulæ* at many levels in the *Seminula* beds.

(*c*) *Argillaceous rocks.*

Thick shales are met with at three levels :—

(1) Throughout the *Cleistopora* beds.

(2) In the upper part of C_2 (*Caninia* dolomite) and in the lower part of S_1.

(3) In the upper part of D_1 and of D_2.

Thin shaly partings occur in upper S_1, in S_2 (*c*), and throughout the more calcareous parts of the D beds, where they are often associated with pseudobreccias.

REVIEWS.

DIE ERUPTIVGESTEINE DES KRISTIANIAGEBIETES. IV: DAS FENGEBIET IN TELEMARK, NORWEGEN. By W. C. BRØGGER. Vid. Selsk. Skrifter I.M.N.Kl. No. 9, pp. 1–408. 1920.

IN a memoir of four hundred pages, furnished with nearly forty mineral and rock analyses, Professor Brøgger has added a fourth volume to his classic series on the eruptive rocks of the Kristiania region.

The Fen district of Telemarken forms a small isolated area of low relief of approximately 4 square kilometers extent, situated on the south-west shores of Lake Nordsjö, and surrounded on its landward borders by abruptly rising Precambrian granites. The area is best approached from Skien, by canal boat to Ulefos on Lake Nordsjö. The occurrence of iron ore and limestone in the Fen region had early attracted the attention of Vogt and other workers, but the unique significance of the area was not appreciated till the discovery by V. M. Goldschmidt in 1918 of microlite, alkali pyroxene, and hornblende, as constituents of the limestones. After this disclosure no further incentive was necessary for a more detailed investigation of the area, which Brøgger has completed in the present memoir.

The rocks comprised within the Fen area include a group of magmatic carbonate rocks, intimately associated with alkaline rocks showing a variable content of primary calcite. No less than thirteen new rock-types have been defined and described from this unique area. The characteristics of these new rock-types and their associated rocks may precede in description the geological history of the Fen region.

(1) *Vibetoite.*

This is the name given to the oldest intrusive of the silicate magma. It is a melanocratic, often coarse-grained rock, practically without felspar or nepheline, and consisting of hornblende, pyroxene, and biotite, and usually rich in apatite (3·51 per cent P_2O_5) and calcite (6·30 per cent CO_2).

(2) *Rocks of the Urtite-Ijolite-Melteigite series.*

These rocks form a continuous series, consisting essentially of nepheline and green pyroxene. The melanocratic member melteigite is a new type from the locality Melteig, and characterized as containing less than 45 per cent nepheline, associated with a green non-aluminous pyroxene (in part aegirine-diopside). True jacupirangite with an aluminous titanium-bearing pyroxene is not recorded in situ. A group of dyke rocks accompany this series, including micromelteigites, tinguaites, and melteigite-pegmatites.

(3) *Rocks of the Tveitåsite-Fenite series.*

These rocks form a probably continuous rock-series, consisting of green pyroxene and alkali-felspar (albite and microperthite). The melanocratic member is tveitåsite, and the leucocratic type is fenite. The fenites are accompanied by corresponding dyke rocks.

(4) *Nepheline-syenite-rocks.*

Quite sparingly distributed is a peculiar type of potash-rich nepheline-syenites, including the new type juvite (6·67 per cent Na_2O, and 8·21 per cent K_2O). This is a medium-grained rock consisting of orthoclase, pseudomorphs of muscovite and cancrinite after nepheline, aegirine, and sparingly biotite. A varietal type is described as biotite-juvite. The melanocratic malignite is also developed. The new rock-type kamperite may conveniently be included here. This rock consists essentially of orthoclase, albite, and biotite. It is a perpotassic type (10·16 per cent K_2O), and the analysis corresponds closely to that of the leucite-basalt of Gaussberg, Antarctica.

(5) *Carbonate-rich rocks.*

(*a*) *Sövite.*—A magmatic carbonate-rock consisting essentially of calcite, with apatite, microlite, biotite, and manganophyllite micas as important accessories.

(*b*) *Rauhaugite.*—A magnesium-rich carbonate-rock ($MgCO_3$ 17·47 per cent, $FeCO_3$ 9·60 per cent), associated with apatite, barite, and magnetite. In the normal rauhaugite, microlite and manganophyllite do not occur.

Apart from large masses of these types, independent dykes of sövite and rauhaugite are developed cutting fenite, etc. The rauhaugite dykes are apatite-rich dolomites (MgO 17 per cent, CaO 31 per cent, P_2O_5 2 per cent.

(*c*) *Mixed Rocks.*—Rocks which must be regarded as mixtures of carbonate magma of sövite type, and of the silicate rocks already enumerated are developed as schlieric intrusions, or as dykes cutting other members of the Fen group. These mixed rocks include hollaite and käsenite, considered as crystallized products of a mixture of calcite magma and ijolite-melteigite magma, the former relatively rich in silicates (pyroxene, nepheline pseudomorphs, melanite, etc.), and the latter with a relatively small content of silicate minerals; further, ringite, a type resulting from a mixture of calcite magma with a fenite magma constituted of calcite, felspar, aegirine and aegirine-diopside, and apatite.

(6) *Damkjernite-sannaite rocks*

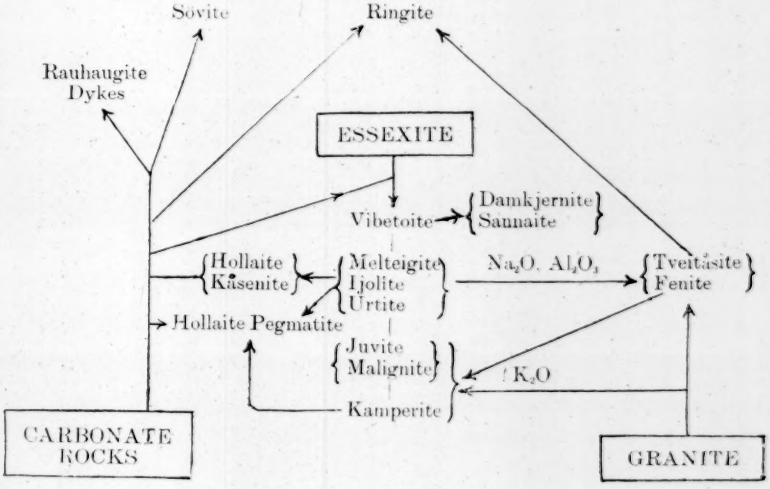
An alnöite-like rock which Brøgger regards as the latest product in the intrusive sequence of the Fen region is described as damkjernite. These rocks are melanocratic members of the alnöite group, and show some variety in composition. The normal type contains large phenocrysts of black biotite, and less commonly

pyroxene, set in a ground mass of pyroxene, apatite, biotite, magnetite, orthoclase, and a small amount of nepheline pseudomorphs. An exceptional type is present as a dyke rock in the Precambrian granite, and contains large barkevikitic hornblende individuals, and nodules of olivine-enstatite, enstatite-diopside, hornblendite, etc., as endogenous inclusions.

Sannaite, which fills an explosion crater at Ormen, 7 kilometers south-west of the Fen region, is a closely related type, forming the end member of the damkjernite-sannaite group. It differs only by the presence of a higher content of alkali minerals. The phenocrysts are of brown-black hornblende, black pyroxene, and sparing biotite in a fine-grained ground mass of alkali-felspar, aegirine, and, in smaller amount, of nepheline pseudomorphs (muscovite).

(7) The latest eruptive rocks of the Fen area are the diabase dykes of post-Silurian date, and which are so constant a feature in the Kristiania region.

The geological history of the Fen region as pictured by Brøgger may now be shortly summarized, the probable genetic relations of the Fen sequence being indicated in the following scheme.



The opening phase in the Fen history was the drilling of an explosion crater in the Precambrian granite. The initial magma was of basic composition, and probably of essexitic type, confirmation of which is provided by the great dominance of the melanocratic melteigite, and also by the interpretation of the oldest vibetoite as an addition product of a calcite magma and a magma of yamaskitic composition (hypermelanocratic differentiation-product of an essexite magma).

The melteigite of the Fen region can, as Brøgger shows, be considered as derived from an essexite magma by admixture with calcite, with removal of certain percentages of anorthite and iron-rich pyroxene, and, further, CO_2, the former by gravitational sinking of crystals; the more leucocratic types, ijolite and urtite, by further sinking of the denser pyroxene.

The ultimate origin of the great mass of carbonate rocks of the Fen region raises a question of great difficulty. The complete resemblance, chemically and petrographically to the undoubted primary dykes of sövite, lead Brøgger to the conclusion that it must be regarded as a primary magmatic rock. Its ultimate source must be a sedimentary limestone which has been completely melted at great depth. By its purity and comparative poorness in silicates, it is sharply distinguished from the variable calcareous sediments of Palæozoic age in the Kristiania district. Still less does the rauhaugite bear resemblance to these, for dolomites are unknown amongst the carbonate rocks of the Kristiania region. Brøgger is of the opinion that the carbonate rocks must be derived by melting (solution) of an *older* limestone *below* the Precambrian granite.

After its melting at great depth, and separation from the carbonate-enriched stem-magma, the great central mass of carbonatite is pictured as forming a lighter layer floating on the heavy silicate magma. Its intrusion into the crater-neck of the Fen led to its crystallization from above downwards. The solid carbonate rock thus formed was penetrated in its outer part by the silicate magma, giving rise to the vibetoite and melteigite-ijolite intrusions. Pneumatolytic addition of phosphorus, fluorine, niobium, and tantalum occurred before consolidation, giving rise to apatite, and microlite in the resulting sövite. On its under side intimate mixtures of silicate magma and carbonate magma were formed, and gave schlieric intrusions of hollaite and käsenite.

The melteigite-ijolite magma has produced an intensive contact-metasomatism in the peripheral Precambrian granite. By the action of solutions an important transfer of soda has taken place. The quartz of the granite is replaced by albite, and the biotite by aegirine, oligoclase is converted to albite, and orthoclase into microperthite and albite, until, at the immediate border, the rock is completely transformed to an alkali felspar-aegirine rock—fenite, or its more melanocratic type, tveitasite. All possible gradations from unchanged granite to the end product fenite can be traced.

That a transition from granite to aegirine-syenite by in situ differentiation is not involved, seems clear from the fact that the destruction of biotite with new-formed needles of aegirine and alkali-hornblende and the development of typical "Schachbrett Albit", so characteristic of secondary felspar, can be traced in thin sections of the transition rocks. Moreover, in intermediate stages some newly formed quartz appears, showing inclusions of aegirine. This quartz, unlike that of the granite, is completely free from

undulose extinction. Fenite also occurs as independent dykes, derived by direct melting (or solution) of granite in melteigite-ijolite magma. These penetrate the melteigite group, and have a typical pulaskitic structure. At the border between the fenite and melteigite group are quite locally developed the juvites and malignites. These are possibly derived from a mixture of fenite and ijolite magmas. Their high content of potash is perhaps to be explained as a direct transfer of potash solutions from the fenitized granite, a process complementary to fenitization itself.

Only in the small sack-shaped area in the vicinity of Melteig are the rocks of the melteigite-ijolite group completely fresh. Elsewhere they are completely or partially changed to muscovite-biotite (chlorite)-calcite-fels. It is probable that the potash absorbed in muscovitization of the already crystallized melteigites is also in part derived from the Precambrian granite.

Whilst the rauhaugite dykes which penetrate the fenite near Ringsevja must be regarded as primary, Brøgger is of opinion that the great eastern mass of rauhaugite is metasomatically derived from sövite. The source of the magnesia and iron, if this be so, must be the rocks of the melteigite group, from the destruction of pyroxene in their conversion to muscovite-chlorite-calcite-fels. Furthermore, this metasomatism must have occurred before the intrusion of the damkjernites, for these contain in places xenoliths of the typical rauhaugite.

Against this view of Brøgger must be placed the fact that the normal rauhaugite does not contain either manganophyllite or microlite. The absence of the latter highly insoluble mineral is significant, and may point to the rauhaugite as an independent intrusion, or, if secondarily changed, a derivative of the magma which gave rise to the primary rauhaugite dykes.

At the conclusion of the fenite formation, and possibly its dyke intrusions, the carbonate magma in part retained its fluidity in depth, and was then erupted, partly as dykes of sövite, and less numerous dykes of rauhaugite, and partly as mixed magmas, as ringite, ringite-pegmatite, hollaite-pegmatite, etc. These latter pegmatites often show characteristic intergrowths of their constituent minerals, e.g. calcite and pyroxene.

Significantly younger than the above rocks and representing the last stages in the intrusive sequence are the damkjernite intrusions which appear as dykes in the granite, in the fenite, in the melteigite group, and in the central carbonatite. Some of the damkjernites contain inclusions of these rocks as well as fragments of older granite and amphibolite. The damkjernites, as well as the sannaite, are late differentiation products of the melteigite group, and show a clear relationship with the earliest intrusive vibetoites. Their resemblance to the African and Brazilian kimberlites has led to a careful search for diamond, but without success.

As to the epoch of intrusion of the Fen rock series, Brøgger was

at first inclined to regard it as an outpost of the Devonian eruptives of the Kristiania region, but later he has come to consider it as of late Precambrian date, in common with the very closely analogous Alnö alkaline area (? Precambrian). The possibility of a Devonian age cannot, however, be wholly excluded. The assumption of selective solution in depth by a Devonian essexite magma, in the presence of mineralizers, of the calcite of an *overlying* impure calcareous terrane of Palæozoic date, seems here not to be entirely precluded. Whatever be the case, one of the most remarkable and so far inexplicable facts, is the absence of typical contact-minerals in the carbonatite.

The last chapter of the memoir is devoted to a critical comparison with the related rock sequences of Alnö, Almunge, Assynt, and other districts. Into this, and into Brøgger's highly interesting discussion of the distribution of Scandinavian alkaline areas with regard to orogenic axes of folding, it is impossible to enter here. Rocks of the Fen region can be matched in all the above-named alkaline fields, but in the Alnö assemblage, with its metasomatised (fenitised) border-zone, the most marked resemblance is provided.

The great work is dedicated "in old friendship" to the investigators of Alnö, the Kola Peninsula and Magnet Cove—Högbom, Ramsay, and Washington.

C. E. Tilley.

Tungsten Ores. By R. H. Rastall & W. H. Wilcockson. Imperial Institute Monographs, pp. ix + 81. 1920. Price 3*s.* 6*d.* net.

THE world depression in trade has sensibly reduced the consumption of ferro-alloys and brought about a heavy fall in the selling price. The interest in this and similar publications is necessarily somewhat limited at the present time. High-speed steel, in which tungsten is an essential constituent, was largely overproduced at the conclusion of the war period, and is still a drug in the market, so that economic conditions are not likely to improve for some time.

The monograph has been compiled from sources indicated in the bibliography included in the volume. It is well compiled, and presents in an abbreviated form the salient features of all the published material on the subject, and should be useful for reference, particularly by those commercially interested in the metal.

Tungsten was one of the metals controlled by Germany before the war, largely in consequence of an indisposition in this country to tackle the problem of the metallurgical treatment of the raw material; and this, notwithstanding that a large proportion of the tungsten mineral is produced within the Empire, and the manufacture of high-speed steel is one of our principal industries. Stern necessity compelled us to evolve processes for production of metallic and ferro-tungsten, and it is hoped that the impetus given by remunerative

war conditions will prevent the industry reverting to Germany, although it may be noted that at the present time that country is the only persistent buyer of tungsten ore. The value of the raw material was 25*s*. to 35*s*. per unit in 1914, but these figures were increased in this country during the war, and more particularly in the United States. So severe, however, is the slump that ore is now worth only 12*s*. 6*d*. per unit c.i.f. U.K. ports, and unless an appreciable rise takes place in the selling price, the cost of production will require severe readjustment.

In dealing with the genesis of tungsten ore, it is noted that they are usually found with tin in granite veins and pegmatites, and much controversy has arisen with regard to the relative temperature of formation of the minerals of these two metals, with a view to determine their occurrence in depth, in Burma and the Malay Peninsula. The authors remark that further information about other occurrences is desirable.

The sporadic occurrence of the mineral prevents any calculations of reserves being made, but its association with granitic rocks in many widely distant areas should guarantee a constantly increasing output, to meet the greater demands which will follow a general trade resumption, by reason of the valuable properties tungsten confers alone, and associated with other metals, on steel.

The remarks on the utilization of tungsten are useful. Whilst Mushet was undoubtedly the first to produce a special tool steel containing tungsten, the term "high-speed steel" was originally applied to a tungsten steel containing molybdenum, first exhibited in 1900. Subsequently British manufacturers made an equally good steel without molybdenum, but in recent years it, and other metals, have been introduced, and changes are made from time to time in the composition and heat treatment of the material in order to obtain the best results.

The use of tungsten for electric lamps is mentioned, and it may be remarked that the production of the wire was impossible, until a process was evolved whereby the ingot was heated in hydrogen to a point below annealing temperature, and subjected to repeated swaging, the effect of which was to elongate the equiaxial grains into fibres of metallic tungsten. In this way tungsten wire was made ductile by a method which usually produced brittleness in other metals. A small quantity of thorium nitrate, added to the tungsten oxide before reduction controls the grain growth, and by coating tungsten with a precious metal or alloy, the product has been found superior to platinum or its alloys in many ways.

The memoir is divided into three chapters, of which the first deals with the occurrence, characters, and uses of the ores, and the second and third with the British and Foreign sources of supply.

The description of occurrences of tungsten ores in the British Empire is good, although possibly greater prominence might have been given to the Burma deposits, having regard to the fact that

they constitute the principal source of British supply, and also because they have been examined and described by competent observers.

The frantic effort during the war to increase output, and/or obtain large profits must have resulted in Burma, as elsewhere, in bad development work and waste, more particularly as the greater part of the output was obtained from alluvial deposits and decomposed ground, worked by sluicing methods. With the return of normal conditions, more reasonable methods of operation will be instituted, and Government control, necessary in such conditions, be made more severe. The description of the Australian deposits is complete, although the output from them is relatively small.

Amongst foreign countries the largest supply comes from the United States, but China and Japan and the South American States and Portugal also produce appreciable quantities.

The fall in the value of the raw material has brought about almost total cessation of work everywhere, and it will be interesting to see from which deposit the mineral can be obtained at the lowest figure, to meet the changed economic conditions of the future.

H. K. Scott.

A Short Account of the Geology of the Isle of Wight. By H. J. Osborne White, F.G.S. Memoirs of the Geological Survey, pp. 219. With 1 Plate (coloured map), and 43 figs. London, 1921. Price 10*s.* net (paper covers).

THE Isle of Wight, on account of its varied structure, its fine coast sections, and its abundant fossils, has always been a favourite subject for study by those interested in geology, and it has now been investigated by at least four generations of scientific men. The results of such study were first brought together in Bristow's memoir, published in 1862, and revised by Mr. Clement Reid and Sir Aubrey Strahan in a second edition issued in 1889, but this work is now out of print. The present guide is intended to replace it, at least in part, and it gives a condensed but admirably presented account of what is now known upon the subject. It is written by one who on account of a long residence in the Island and an intimate acquaintance with its geological features is exceptionally well qualified for the task which was entrusted to him by the Geological Survey.

After a short chapter on the main physical features, and containing a table of the formations, the author describes in order the stratigraphical series beginning with the Wealden and passing upwards to the Hamstead beds of the Oligocene. The section on the Chalk has been much amplified as compared with that in the earlier Memoir, and it contains several new diagrams and sketches of coast exposures. The account of the stratigraphy is followed by a chapter on the tectonic structure of the Island and the post-Oligocene disturbances to which it has been subjected, and here

also a good deal of new matter is included. Not the least interesting part of the book is that dealing with the ancient river systems, and describing how the rivers arising in the south have had their valleys truncated by coast erosion, which is still going on, as may be seen by any visitor to Freshwater Bay and other places on the southern shore. It is shown, for example, how the Western Yar, which now opens into the Solent by a mouth disproportionately large for the size of the river, and rises a few yards from the sea at Freshwater Gate, once had a course extending eastward past Brook and Brighstone (here written Brixton) on the south of the chalk downs and as far as Blackgang and Atherfield, as is demonstrated by the gravels and brickearths exposed in the sections of the cliffs. These and other formations are well described in the chapter on superficial deposits. It is followed by a section on the economic geology, containing further new material, with good accounts of the different soils, of the building materials (and notably that supplied by the Bembridge limestone), of the road metal, the scanty fuel supplied by the brown coal-seams of the Bracklesham beds and the peat on Wroxall Down, and the phosphatic concretions and other minerals collected in small quantity in various parts of the island. The volume concludes with a chapter on the water supply. As already indicated the work is based on the Survey Memoir of 1889, but it is enriched by original observations by the author. It is intended to accompany the large-scale colour-printed map also issued by the Survey, for the map forming the frontispiece is inadequate, and compares very unfavourably with that which appeared in the earlier Memoir. The omission of the figures of the characteristic fossils is to be regretted in a work intended mainly to be popular. The tables of fossils and the other appendices to the former Memoir are likewise excluded, but this may be regarded as inevitable in view of the small compass of the book, the present volume containing 219 pages, as against 349 pages to the Memoir of 1889. Nevertheless, the price of Mr. Osborne White's memoir is 10*s.*, while that of the earlier and larger volume was 8*s.* 6*d.* This is a matter for regret, since a reliable and comprehensive book, such as Mr. White's work undoubtedly is, if sold at a more moderate price would almost certainly command a large sale among the visitors to the island.

F. H. A. M.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

1st November, 1921.—Dr. A. Hutchinson, President, in the chair.

Professor H. Hilton: On the determination of the optic axes of a crystal from extinction-angles.

The problem of obtaining the positions of the optic axes of a crystal from the extinction-directions on four known faces was discussed,

and it was shown from a purely geometrical standpoint that the solution is unique. Their position was also found graphically as the intersection in the gnomonic projection of two cubic curves, on which any number of points can be obtained by the use of the ruler only.

W. Campbell Smith : On some minerals from Leadhills.

Caledonite of pale-blue colour and acicular habit has been frequently described in the past as aurichalcite. Examination of all available specimens of so-called aurichalcite from this locality showed that all were caledonite of this acicular habit. The optical properties were found to agree with those of caledonite of the normal habit. It was shown that in caledonite the plane of the optic axes is parallel to (010) and the acute bisectrix is perpendicular to (100), and not as stated in Dana and other textbooks. Other remarks referred to gold, linarite, minium, and the rare mineral eosite.

Dr. J. Drugman : An example of porphyry-quartz from the Esterel Mountains (France) twinned on the face ($10\bar{1}2$).

This twin-law in quartz has previously been observed only by Q. Sella in 1858 and has been regarded as doubtful. An example of it has been found amongst the porphyritic crystals in the "blue porphyry" of the Esterel Mountains. A distinction is made between the twins of low-temperature rhombohedral α-quartz and those of hexagonal β-quartz (stable at a temperature above 575° C.).

Dr. L. J. Spencer : Biographical notices of mineralogists recently deceased ; with an index of those previously published in the *Mineralogical Magazine*.

Edinburgh Geological Society.

19*th October*, 1921.—Mr. T. Cuthbert Day, F.R.S.E., F.G.S., President, in the chair.

"The History and Development of the Yorkshire, Derbyshire, and Nottinghamshire Coalfield." By Dr. Walcot Gibson, F.G.S., Assistant to the Director for Scotland, H.M. Geological Survey.

The lecturer pointed out that the area beneath which coal under a depth of 4,000 feet in considered as proved, amounted to 2,136 square miles, containing an actual coal reserve of over 41 thousand millions of tons. Many of the valuable seams lie under 3,000 feet depth, and there is a considerable area falling within the depth of 2,500 feet.

Dr. Gibson showed that the sequence was common to all the coalfields of the Midland area, roughly estimated at 8,000 square miles, even to the persistence of individual seams of coal and thin beds of shale containing a characteristic marine fauna. Only a partial resemblance can be instituted with the northern group of coalfields—including Scotland—or with those of the south and south-west of England.

Special points arising from the examination of the Midland sequence and of general significance are : (1) The existence of a floral break between the Upper and Lower Carboniferous rocks in North

Staffordshire; (2) the incoming of marine conditions in the Millstone Grits as they are traced northwards; (3) the possible correlation of the Alton (Ganister) Coal and its marine roof with the Slatyband Ironstone of Scotland, a correlation adopted by Hull; (4) the probable Lanarkian age of the measures below the Kilburn Coal of North Derbyshire; (5) the many marine bands containing Productids in the Westphalian (Middle) Coal Measures of the Midland Province; (6) a considerable thickness of barren measures not infrequently of a red colour, high up in the Westphalian Coal Measures, but below the Staffordian Coal Measures, and their possible correlation with the barren red measures of Fife and Midlothian; (7) the not infrequent occurrence of a marine bed resting directly on a seam of coal and the persistence of such seams of coal even when a few inches in thickness.

CORRESPONDENCE.

THE MAGNESIAN GROUP OF IGNEOUS ROCKS.

Sir,—The interesting paper appearing in your November number under the title: "The Magnesian Group of Igneous Rocks," raises a number of points which seem to require some further discussion. It is to a few of these only that I wish to refer here. The application of the term "magnesian" to a group of igneous rocks, the ultrabasic members of which alone show notable content of MgO, is an innovation that appears scarcely justified. In the intermediate and acid types it is iron and not magnesium which calls for note. The peculiar properties of this group of rocks are of a provincial order in a petrographic sense, and serve to rank the group as a distinct unit of the calc-alkaline suite, rather than a group co-ordinate with this suite. Amongst the "magnesian" provinces listed by Mr. Dixey there are some whose inclusion requires some further word of explanation. Number 7, in particular, finds itself among strange companions. Some of the characteristics of these rocks are explicable on the assumption of a low active mass of water in the magma, combined in certain cases with high pressure during consolidation.

A low magmatic water content may lead to an early precipitation of potash felspar, and we may note that orthoclase or microperthite is a not uncommon feature in the basic types, as in the Norwegian norites and the basic members of the Eyre Peninsula group. It is to this early precipitation of potash felspar that the occurrence of oligoclase or andesine as the plagioclase constituent of the microperthite in the basic types is due. This feature is best exemplified in the rocks of Western Norway. The occurrence of hypersthene in the intermediate and acid types is probably explicable on these lines. In the absence of abundant water the degradation of the metasilicate molecule to the orthosilicate type is inhibited, so

that hypersthene appears instead of biotite, as in the equation

$$\text{biotite} + \text{quartz} \rightleftharpoons \text{hypersthene} + \text{orthoclase}.$$

The presence of garnet (almandine) in the more acid types at least, is also an expression of a low active mass of water to which may be added the influence of high pressure (*Q.J.G.S.*, 1921, p. 94). While the occurrence of hypersthene in acid charnockitic rocks may thus be ascribed to a comparative poorness in magmatic water, it is of interest to note that hypersthene is also found in acid rocks which otherwise cannot be included in this group. In such abnormal cases its presence can be ascribed to hybridism. This is the case with certain acid gneisses in the island of Rum, described by Dr. Harker. The conversion of olivine to enstatite (hypersthene) supplies an explanation in some cases where olivine is a constituent of the absorbed material. The monoclinic pyroxene of acid igneous rocks is characteristically a non-aluminous type, and it is not improbable that an aluminous type is unstable in the presence of quartz. Where acid rocks have been contaminated with basic material such as gabbro, the aluminous pyroxene of the latter might be expected to react with silica as in the equation :—

$$\left.\begin{matrix} x\mathrm{CaMgSi_2O_6} \\ 2\mathrm{MgAl_2SiO_6} \end{matrix}\right\} + 3\mathrm{SiO_2} = x\mathrm{CaMgSi_2O_6} + (2\mathrm{MgO_2Al_2O_3}, 5\mathrm{SiO_2})$$

with the production of cordierite. But, as is well known, in contact metamorphism cordierite and diopside are mutually exclusive, and the products of this reaction under hydrostatic conditions would probably react with the production of anorthite, enstatite (hypersthene), and quartz, thus :—

$$2\mathrm{CaMgSi_2O_6} + \mathrm{Mg_2Al_4Si_5O_{18}} = 2\ \mathrm{CaAl_2Si_2O_8} + 4\mathrm{MgSiO_3} + \mathrm{SiO_2}.$$

Cordierite, being a common product of thermal metamorphism, it might be expected that hypersthene would similarly arise if diopside were present in the invading magma, by assimilation of aluminous sedimentary material. In this modified sense there may be some justification for Dr. J. W. Evans' contention, mentioned by Mr. Dixey, when applied to cases where hybridism can be proved on other grounds. It is of interest to note in this connexion the example afforded by the norite intrusions of Huntly, Aberdeenshire, described by Mr. W. R. Watt (*Q.J.G.S.*, 1914, p. 266). Monoclinic pyroxene is a normal constituent of the norite, but where the latter has been subject to contact metamorphism or has intruded sediments with transference of material, cordierite appears, but diopside is conspicuous by its absence.

C. E. Tilley.

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